



NRL/MR/6180--01-8549

# **Preliminary Evaluation of the Performance of Remote Controlled Firefighting Platforms in Combating Flight Deck Fires**

J.T. LEONARD

*GEO-CENTERS, Inc.  
Lanham, MD*

R.C. BELLER

R.E. BURNS

R.L. DARWIN

E.J. JABLONSKI

*Hughes Associates, Inc.  
Baltimore, MD*

F.W. WILLIAMS

*Navy Technology Center for Safety and Survivability  
Chemistry Division*

April 23, 2001

20010509 068

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE April 23, 2001		3. REPORT TYPE AND DATES COVERED Final
4. TITLE AND SUBTITLE Preliminary Evaluation of the Performance of Remote Controlled Firefighting Platforms in Combating Flight Deck Fires			5. FUNDING NUMBERS PE - 0603216N PR - W1819	
6. AUTHOR(S) J.T. Leonard,* R.C. Beller,** R.E. Burns,** R.L. Darwin,** E.J. Jablonski,** and F.W. Williams				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Research Laboratory Washington, DC 20375-5320			8. PERFORMING ORGANIZATION REPORT NUMBER NRL/MR/6180--01-8549	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Naval Air Systems Command 47123 Bus Road Patuxent River, MD 20670			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES *GEO-CENTERS, Inc., Lanham, MD **Hughes Associates, Inc., Baltimore, MD				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)  Based on the results of these tests it would appear that, while the Remote Control Firefighting Platform (RCFP) could be a valuable adjunct to the existing fire extinguishing equipment available on the flight deck, it would probably not be the primary response vehicle in many fire situations. However, in major conflagrations, especially when ordnance is involved, it could provide the capability to control or extinguish many fires, which might otherwise burn until the fuel supply was exhausted. (This delay is unacceptable, as returning aircraft often have no alternative landing area and because of the high probability of ordnance cook off in a prolonged flight deck fire.) The RCFP could provide a means of approaching fires from downwind and attacking fires behind or within debris. The RCFP also could provide ordnance cooling capability without unduly endangering personnel.				
14. SUBJECT TERMS Fire fighting      Robotics Flight deck      Remote fire fighting			15. NUMBER OF PAGES 29	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

## CONTENTS

1 0	INTRODUCTION .....	1
2.0	OBJECTIVE .....	4
3.0	TEST FACILITY DESCRIPTION .....	4
4.0	TEST PROCEDURE .....	8
5.0	TEST PROGRAM .....	11
5.1	Vehicle Approaching With the Wind (Upwind) .....	11
5.2	Vehicle Approaching Against the Wind (Downwind) .....	11
5.3	Night Tests .....	11
5.4	Tests of RCFP Modifications .....	13
5.5	Tests of Increased Nozzle Flow .....	13
6.0	RESULTS: NON-FIRE TESTS .....	13
7.0	RESULTS FIRE TESTS .....	13
8.0	SUMMARY AND CONCLUSIONS .....	25
9.0	RECOMMENDATIONS .....	25
10.0	REFERENCES .....	26

# **PRELIMINARY EVALUATION OF THE PERFORMANCE OF REMOTE CONTROLLED FIREFIGHTING PLATFORMS IN COMBATING FLIGHT DECK FIRES**

## **1.0 INTRODUCTION**

The Remote Control Firefighting Platform (RCFP) concept was developed as an addition to the present complement of firefighting equipment available to aircraft carrier crash/salvage crews. The main advantage of the RCFP is its ability to move into an area where the incident heat flux level exceeds the protection of a fire proximity suit. Thus the RCFP is able to approach an uncontrolled fire from the downwind side, something which proved impossible for the crewmen combating the fire on the USS NIMITZ on May 26, 1981 [1]. The RCFP also provides the capability to cool ordnance, which could cook-off at any time, without exposing crewmembers. Present NATOPS procedures require firefighters to operate from a minimum of 15 m (50 ft) away when ordnance cook-off is imminent [2].

Two RCFP prototypes were developed by the Naval Surface Weapons Center to provide initial validation of the RCFP concept, as well as to identify improvements for future designs. One of the vehicles, designated the Firecat, was a battery-powered, tracked vehicle (Figure 1), and the other, the Firefox, a gasoline driven, skid steer vehicle (Figure 2).

The RCFP prototypes were tested against a standard debris pile fire, which included a running fuel fire, generally recognized as the most challenging type of flammable liquid fire to extinguish [1]. The RCFPs were tested singly and in joint operations under a variety of approach angles, wind conditions and nozzle flow rates. A number of tests were run with various modifications to the basic RCFP prototypes, such as the addition of a boom to improve nozzle reach. Also, several tests were run at night with light provided only by the burning debris pile. A total of 45 fire tests were conducted.

The basic flow rate for both RCFPs was 946 Lpm(250 gpm), although a number of tests were run utilizing flow rates as high as 1893 Lpm(500 gpm). In addition, multiple tests were conducted utilizing tie-down chains and debris to create obstacles, to assess the maneuverability of the vehicle and operational skills required. These latter tests will be reported by the Naval Surface Weapons Center.

As stated above, these tests were designed to provide an initial validation of the RCFP concept. The prototype vehicles operated without support from other firefighting "systems" which could be expected in flight deck operations, e.g. the flush deck system or hand lines. In addition, the vehicle approach path was limited to simulate a single path available through debris on the deck, further limiting the ability of the operator to maneuver the vehicle.



## Firecat

- Commercial grade tracked firefighting platform
- Power -6 marine lead/acid batteries
- Drive -2 electric motors, 36 VDC, 2.5 hp each
- Turret -250 to 1000 gpm
- Weight -2000 lbs

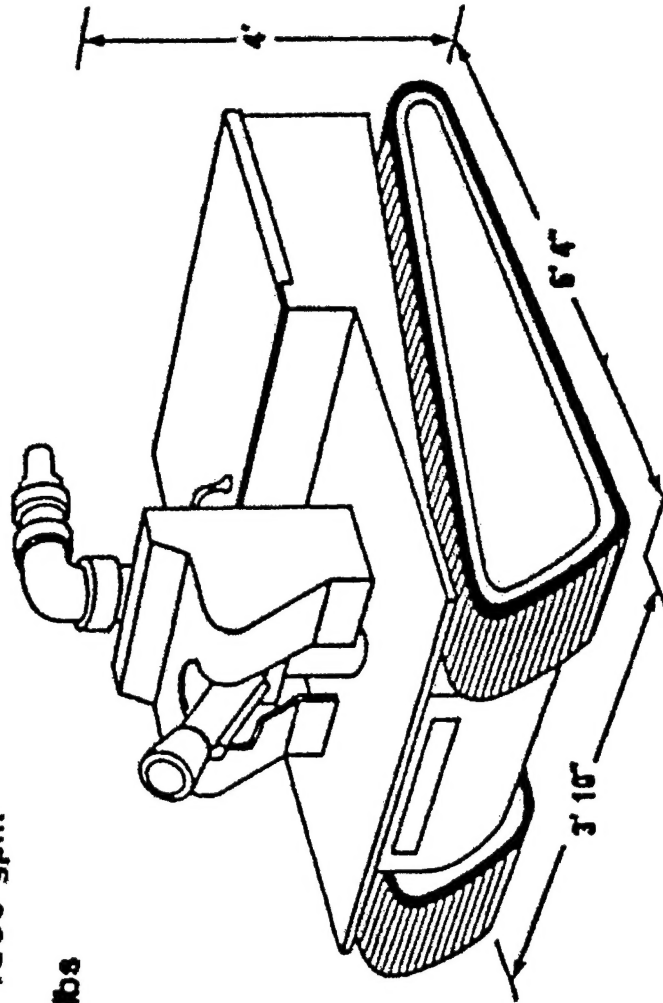


Figure 1 - Firecat

## Firefox

- Modified front-end loader, 4-wheel skid steer
- Power - 2 cylinder, 17hp gasoline engine
- Drive - electrically actuated hydraulic motors
- Turret - 250 gpm
- Weight - 2100 lbs

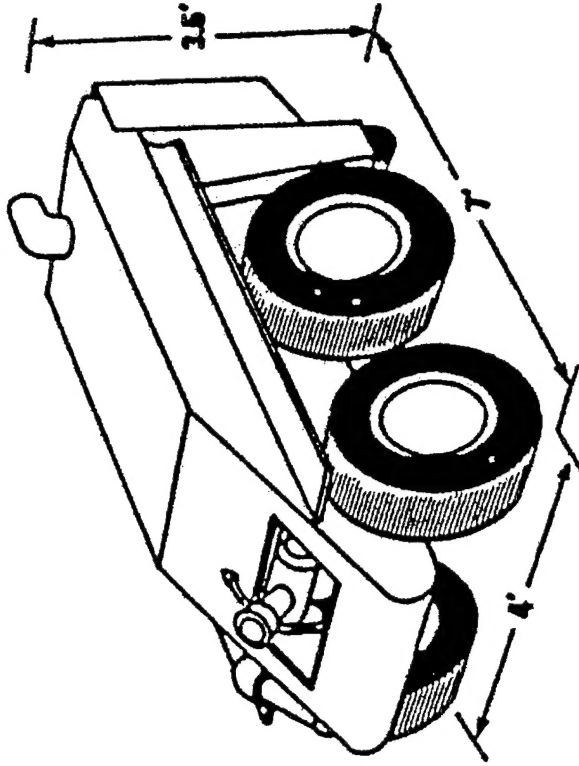


Figure 2 - Firefox

## **2.0 OBJECTIVE**

The objective of the test program was to determine if RCFPs could be successfully deployed to extinguish aircraft carrier flight deck fires, particularly when there is a danger of ordnance cook-off. Specific questions to be answered were:

1. Can the RCFP be maneuvered over and around debris on the flight deck to find an optimum approach for extinguishing the fire?
2. Can the RCFP reach the fire in a timely manner?
3. What is the maximum distance from which the RCFP can extinguish the fire under various wind conditions up to 30 knots and angles of attack with respect to the wind.
4. Can the RCFP be successfully deployed at night?

## **3.0 TEST FACILITY DESCRIPTION**

The full scale fire testing of the prototype RCFPs was conducted at the Naval Research Laboratory's Fire Test Facility, Chesapeake Beach Detachment (CBD). This facility has a concrete "flight deck" measuring 15.3 m (50 ft) by 22.9 m (75 ft) as shown in Figure 3. The "flight deck" was increased in size for these tests by installing 6.1 m (20 ft) of steel deck plate, on concrete supports, along two of the sides. This gave the deck an overall dimension of 21.4 m (70 ft) by 29 m (95 ft). The deck plate was coated with non-skid to evaluate the maneuverability of the RCFPs under more realistic conditions. The flight deck also had a simulated flush deck AFFF/washdown system, but it was not used in these tests.

The standard debris pile fire, which was utilized as the test fire in all cases, was originally developed during the NIMITZ fire test program to simulate an aircraft crash and fire scenario on the flight deck of an aircraft carrier [1]. The debris pile is essentially a box with a partially open lid, as shown in Figure 4. The "box" is a rectangle 2.9 m (9.5 ft) by 3.7 m (12 ft), with a height of 1.6 m (5.25 ft). The walls are constructed of concrete block with openings between blocks for air flow. The "lid," or roof, is a steel plate with four legs made of steel pipe. The legs are placed within the pile and the roof is slanted at an angle of approximately 16 degrees with respect to the side walls. This leaves an opening height of 0.8 m (2.75 ft) in front, while the roof touches the top of the back wall. The sides of the roof are also open. The fuel source is a horizontal section of 10.2 cm (4 in.) steel pipe with a 1.3 cm (0.5 in.) wide slit running the length of the pipe. JP-5 jet fuel is pumped into the horizontal pipe, out of the slit, and down a cascade of six metal trays with alternating front to back slopes, providing a running fuel fire, as shown in Figure 5. The excess fuel runs to the bottom of the debris pile creating a pool fire there. The flow rate of the JP-5 during the test is 189/min (50 gpm).

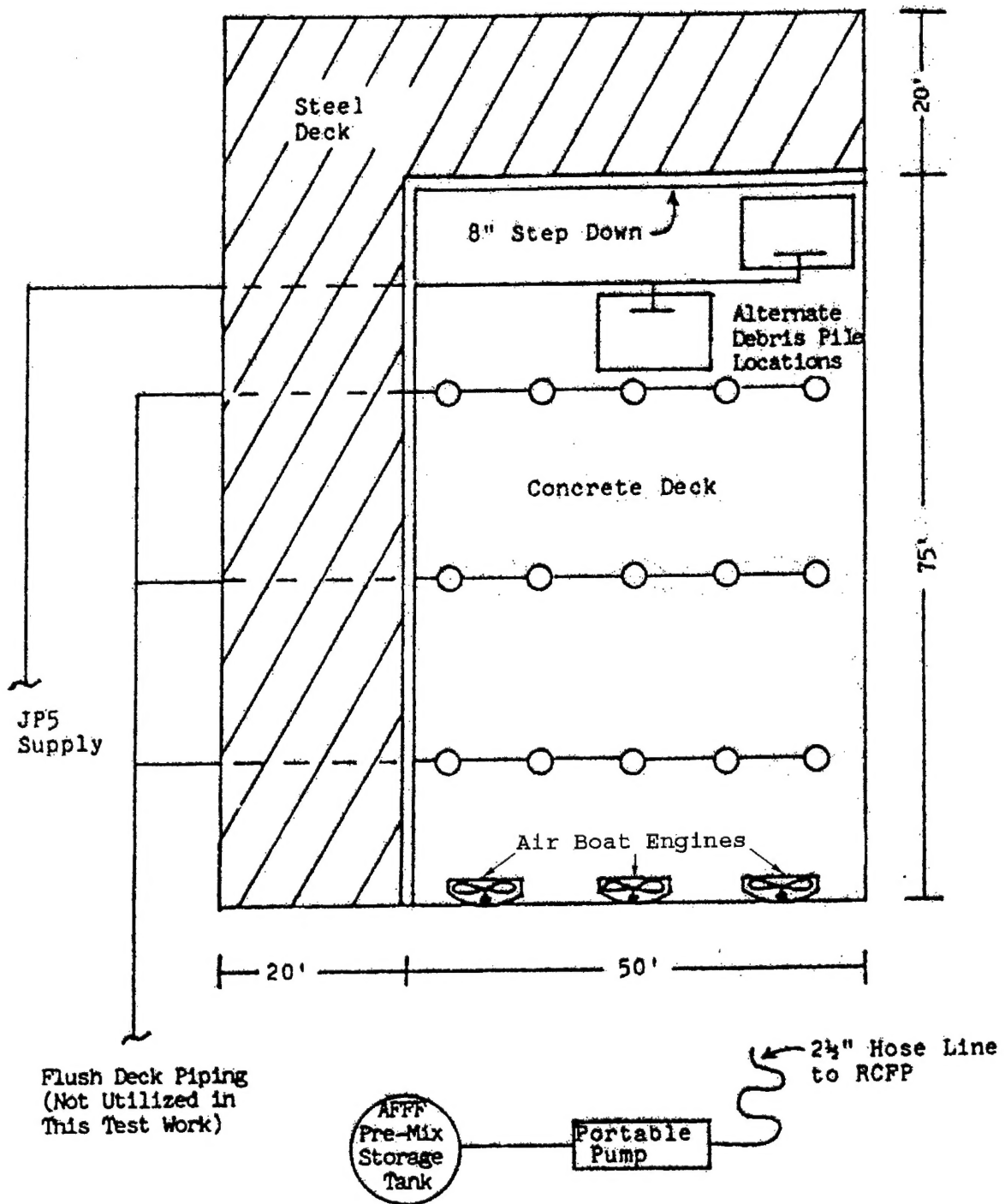


Figure 3 – Flight decks at NRL's CBD test site

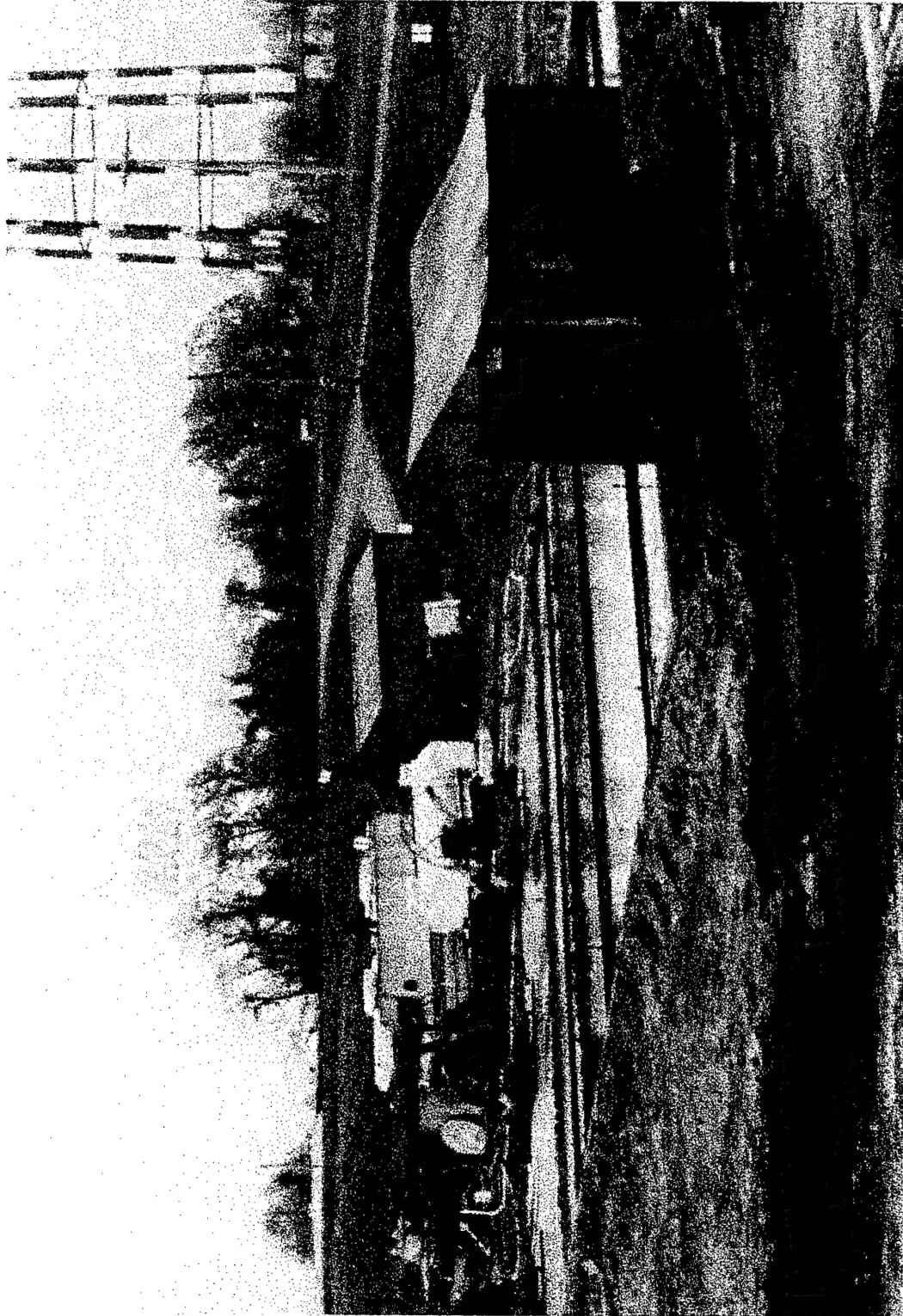


Figure 4 – “Standard” debris pile fire

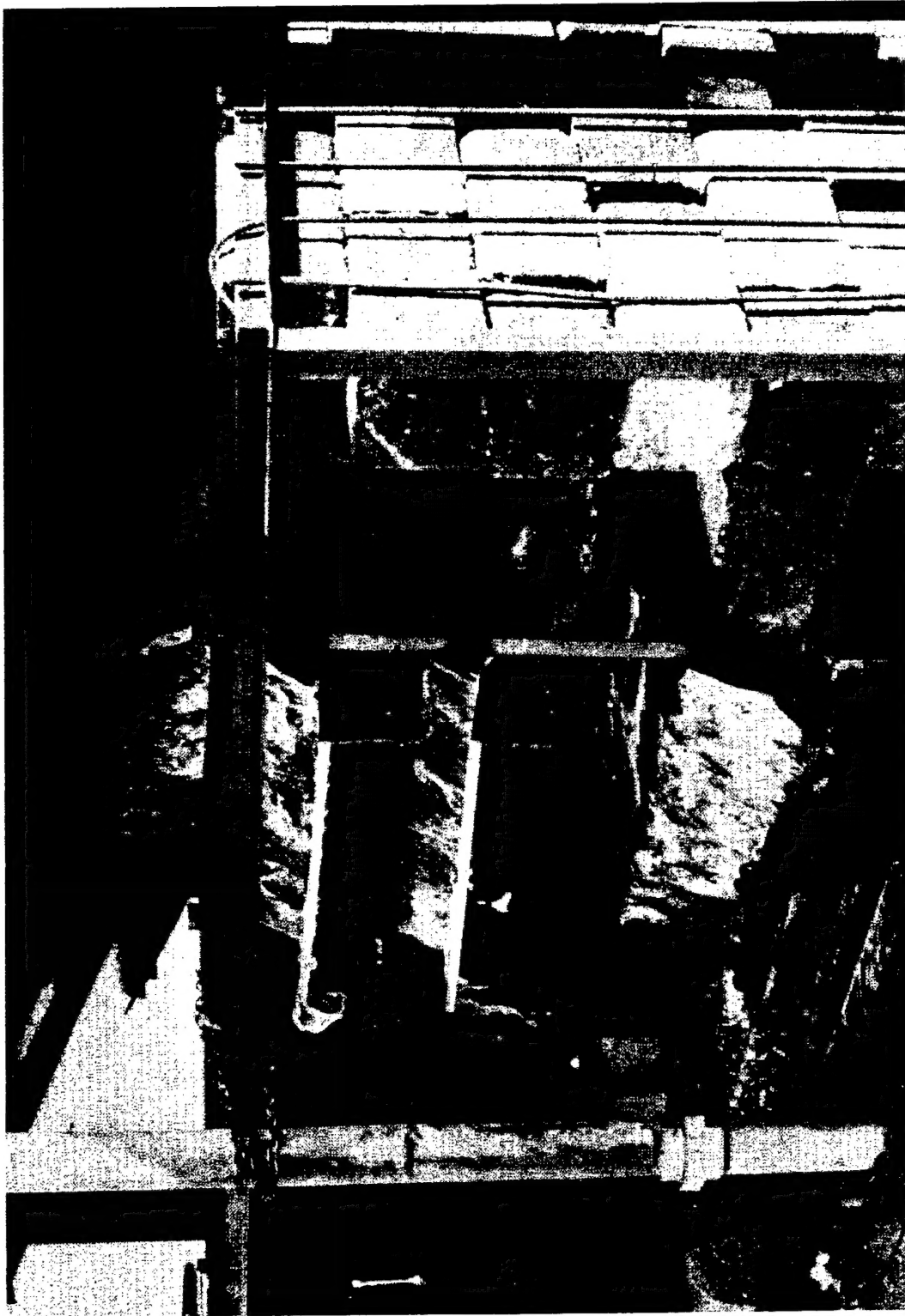


Figure 5 – Running fuel cascade in debris pile

Simulated wind conditions of 15 and 30 kts were used to represent actual carrier conditions. The wind generation equipment at this test facility consists of three air boat engines, with 2.4 m (8 ft) wooden propellers, mounted on a steel support framework (Figures 6 and 7). By varying the engine RPM's, the wind velocity can be set to the desired level, using a hand held anemometer.

In several of the tests, pieces of scrap metal were placed fairly close together over the entire deck surface. This was meant to represent debris scattered across the deck after an aircraft mishap, or as a result of weapons cook-off. The RCFP operators were required to maneuver over these pieces of scrap to demonstrate the vehicle's ability to climb over minor obstacles. Charged hose lines were also placed in the path of the vehicles in order to determine if they would be damaged by the passage of the RCFP over them.

The AFFF supply to the RCFPs was provided by a portable pump taking suction from a tanker filled with premixed foam solution. The foam solution was made from 6% AFFF concentrate. The flow rate to the hose stream supplying the nozzle mounted on the RCFP was measured by a flow meter. Nozzle pressure was measured for the stream reach and flow capacity tests conducted before the first fire test. The flow rate for the majority of the tests was 946 Lpm(250 gpm), however several tests were run with increased flows as high as 1893 Lpm (500 gpm). In addition, several tests were run utilizing both RCFPs simultaneously, at flow rates of 946 Lpm (250 gpm) each, for a total flow of 1893 Lpm(500 gpm). Each RCFP was equipped with a variable pattern nozzle which could be oscillated as well as elevated by the operator. The nozzles were supplied by 6.4 cm (2.5 in.) soft hose lines which were connected to the discharge of the portable pump described above.

#### **4.0 TEST PROCEDURE**

Before each fire test the RCFP was positioned in line with the designated approach angle for that specific test. The original distance from the debris pile was noted once the vehicle was in the desired location. The operator was then briefed about the parameters of the approach he was to make.

The flow of JP-5 was begun approximately 30 seconds before ignition in order to ensure that fuel was flowing across all surfaces and collecting on the floor of the debris pile. At this point, an accelerant was dumped into the debris pile and ignited. A pre-burn period of at least 30 seconds was utilized to ensure complete involvement of the fuel.

After full involvement, the operator was directed to proceed. The operator would then move the RCFP forward, within the limits of his instructions, and begin application of the AFFF while continuing to approach the fire. The flow of JP-5 was continued at 189 Lpm (50 gpm) until extinguishment, or until the test was declared over. Measurement of the time to control or extinguishment was initiated at the moment the RCFP began to apply foam. The time of control, or extinguishment, if achieved, was recorded as well as the final distance of the vehicle from the debris pile. Observations of any unusual conditions were also recorded. The AFFF flow, taken



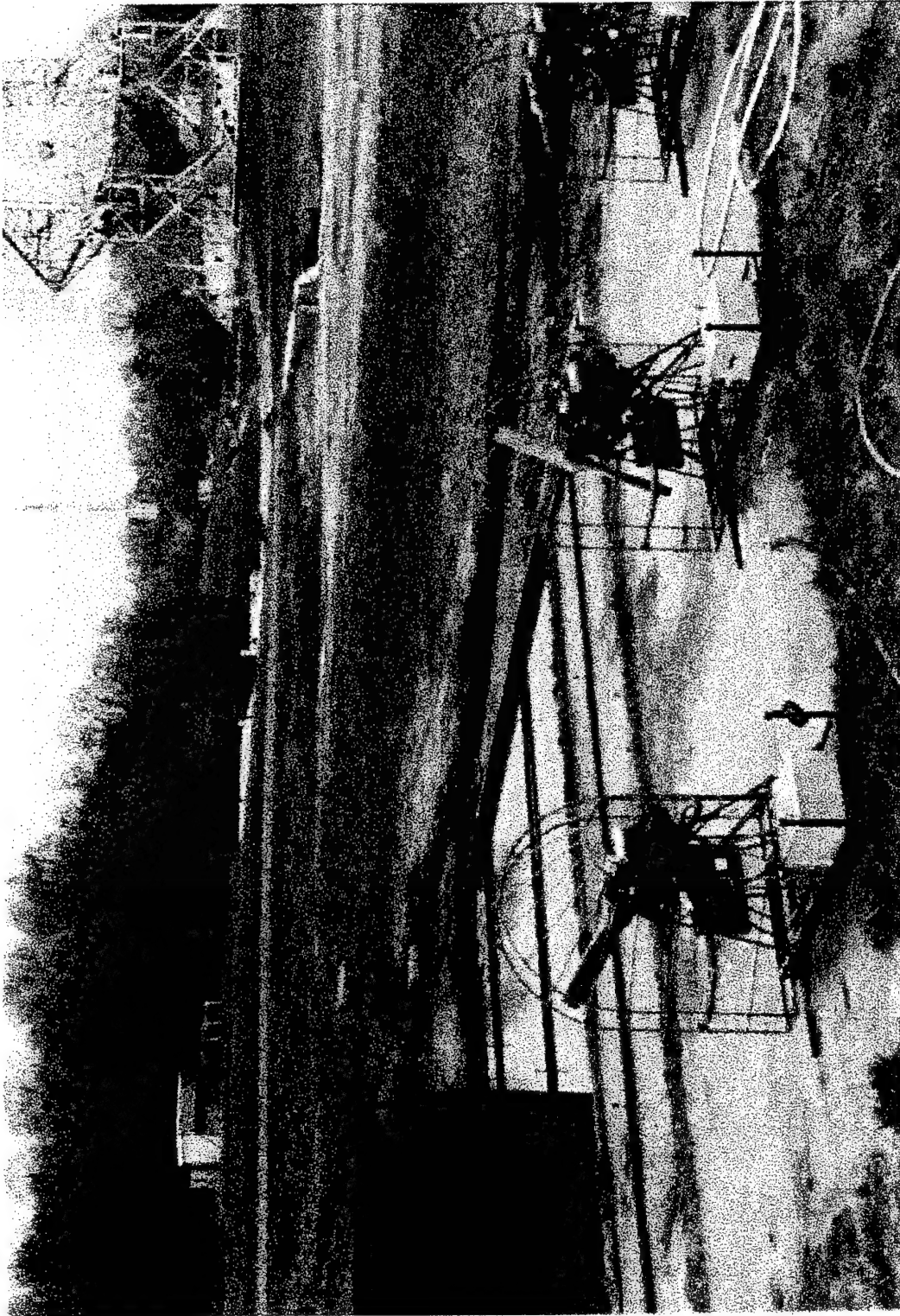


Figure 6 – Air boat engines facing the debris pile



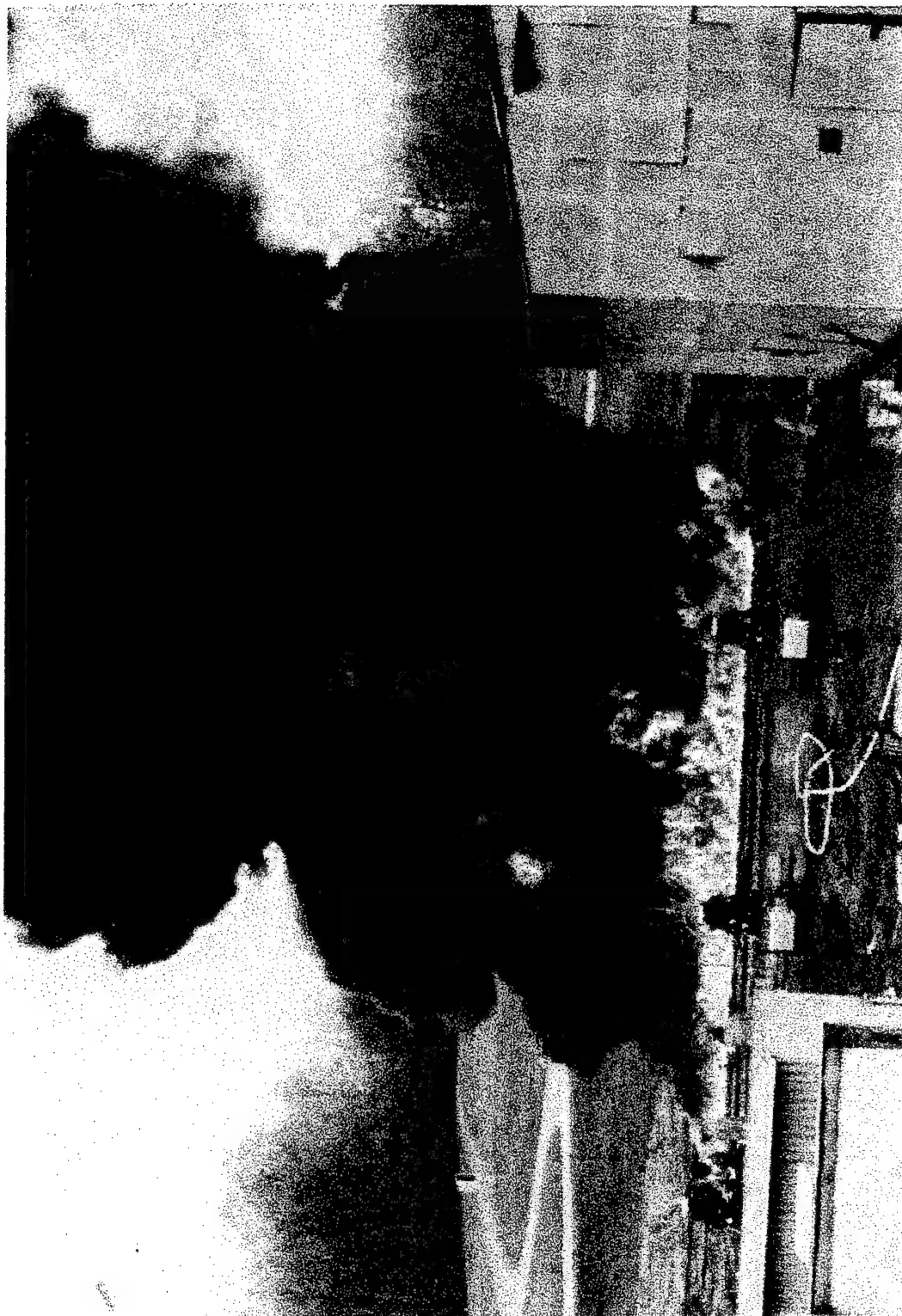


Figure 7 – Air boat engines fanning a flight deck fire

from the flow meter reading, and wind velocity were noted during each test. During six of the final seven tests the temperature profiles of the ordnance mock-ups were recorded.

Four additional tests were conducted utilizing only hand held nozzles in order to provide a base against which the RCFPs performance could be evaluated. All four tests were conducted with a single nozzle operating 15.3 m (50 ft) away from the debris pile. Two tests were conducted crosswind and two were into the wind. One 3.8 cm (1.5 in.) hose and one 6.4 cm (2.5 in.) hose were utilized from each of the two positions.

## **5.0 TEST PROGRAM**

A total of 45 tests were conducted using both RCFPs. The main variables examined were; approach direction (with respect to the debris pile location and relative to the wind direction), e.g. upwind of the debris pile (approach with the wind) and downwind of the debris pile (approaching against the wind), and the angle of the approach with respect to the wind. The approach angle was varied in both the upwind and downwind cases from 0 degrees (straight into or with the wind), to 30 degrees and 60 degrees, and finally to 90 degrees (crosswind). This resulted in the following groups of tests for both RCFPs:

### **5.1 Vehicle Approaching with the Wind (Upwind).**

Tests were conducted at approach angles of 0, 30, 60 and 90 degrees with the wind.

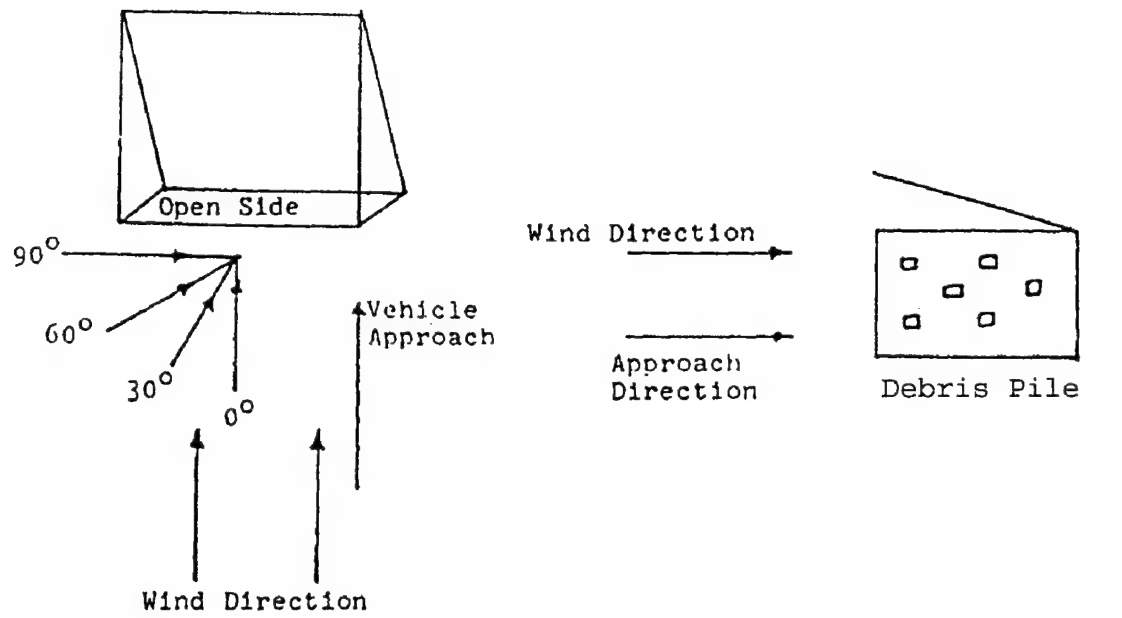
### **5.2 Vehicle Approaching against the Wind (Downwind).**

Tests were conducted at approach angles of 0, 30, 60 and 90 degrees against the wind.

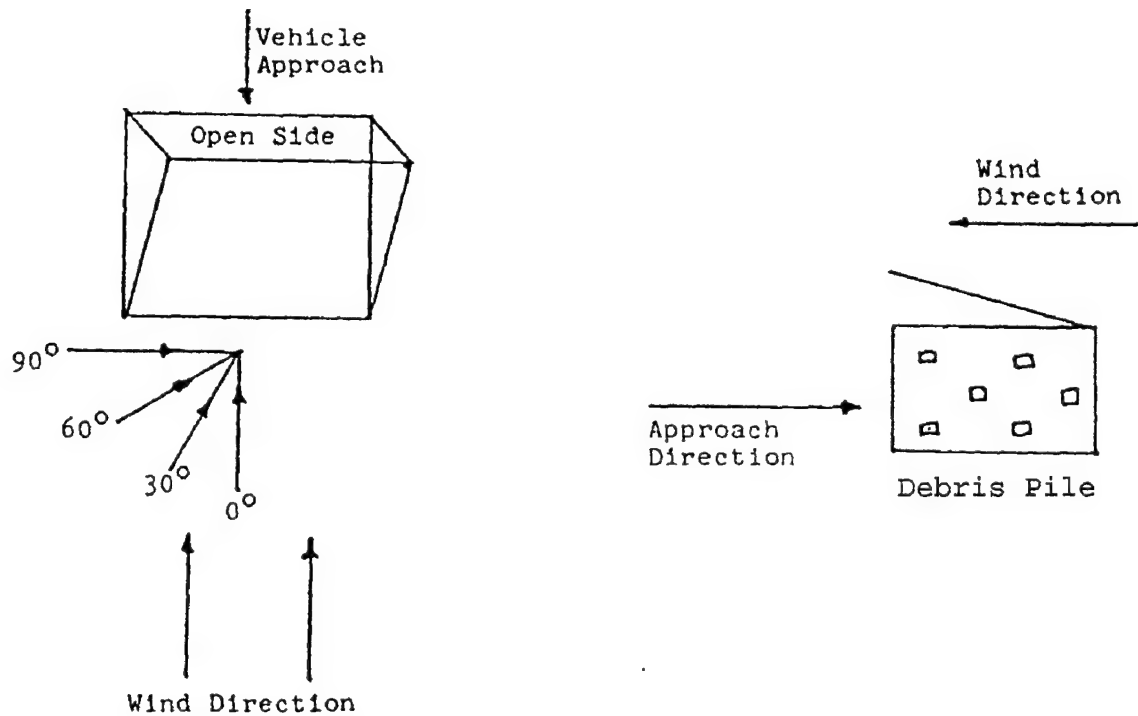
The two crosswind (90 degree) approaches may appear to be identical, however in all cases the debris pile was open to the direction from which the vehicle was approaching. In other words, the RCFP vehicle was always applying foam into the front (and side) of the debris pile. In the case of the 90° upwind approach, the wind blows into the opening, while in the 90° downwind approach, the wind blows over top of the roof. The configurations are detailed in Figure 8.

### **5.3 Night Tests**

Another group of tests was run at night, with no artificial lighting. The vehicle operator had only the light of the fire to see and was not sure of the exact direction of the nozzle until the agent discharge began. Measurement of extinguishment time began at initial agent flow, regardless of whether more maneuvering was required to place the stream more effectively. This group of tests was designed to determine the effect on the vehicles' capabilities if the carrier deck should lose its lighting.



VEHICLE APPROACHING WITH THE WIND (UPWIND)



VEHICLE APPROACHING AGAINST THE WIND (DOWNWIND)

Figure 8 – Wind direction and approach angles for RCFP

## **5.4 Tests of RCFP Modifications**

Two other groups of tests involved modifications to the original prototypes. One modification was the installation of the Feecon nozzle, which was a variable flow, constant pressure nozzle, in place of the standard Akron nozzle. The second modification was the installation of a 2.4 m (8 ft) boom with the Feecon nozzle on top, on the Firefox vehicle.

## **5.5 Test of Increased Nozzle Flow**

The final test grouping, overlapping somewhat with some of the previous groups, involved tests with increased flow of AFFF. This increased flow was provided by either use of both vehicles against the same fire, or by increased flow from a single vehicle nozzle.

## **6.0 RESULTS: NON-FIRE TESTS**

In addition to the fire tests, preliminary tests were conducted to determine the operating characteristics of the firefighting nozzles on both prototype RCFP vehicles. As indicated in Figure 1, the Firecat is equipped with a 1000 gpm nozzle, whereas the Firefox (Figure 2) has a 250 gpm nozzle. The differences in the two nozzles became more evident at nozzle pressures above 70 psi where the flow rate of the Firecat nozzle continues to increase with increasing pressure, while the Firefox nozzle is limited to 300 gpm as shown in Figure 9.

Preliminary tests were also conducted to determine the lateral range of the stream from each RCFP vehicle, in a no wind condition, at differing angles of nozzle elevation. A photo of the Firecat during the stream reach test is given in Figure 10. The results of the stream reach tests for the Firecat are presented in Figure 11, while those for Firefox are given in Figure 12. These Figures show that there is no significant difference between the two nozzles with respect to stream range at nozzle angles of 0-30 degrees.

## **7.0 RESULTS: FIRE TESTS**

The fire test results are presented in tabular form in the following order:

Table 1 – Results with RCFP approaching with the wind

Table 2 – Results with RCFP approaching against the wind

Table 3 – Results for night fires

Table 4 – Effect of using a 2.4 m (8 ft) boom on firefighting

Table 5 – Effects of increased flow rates on extinguishment time

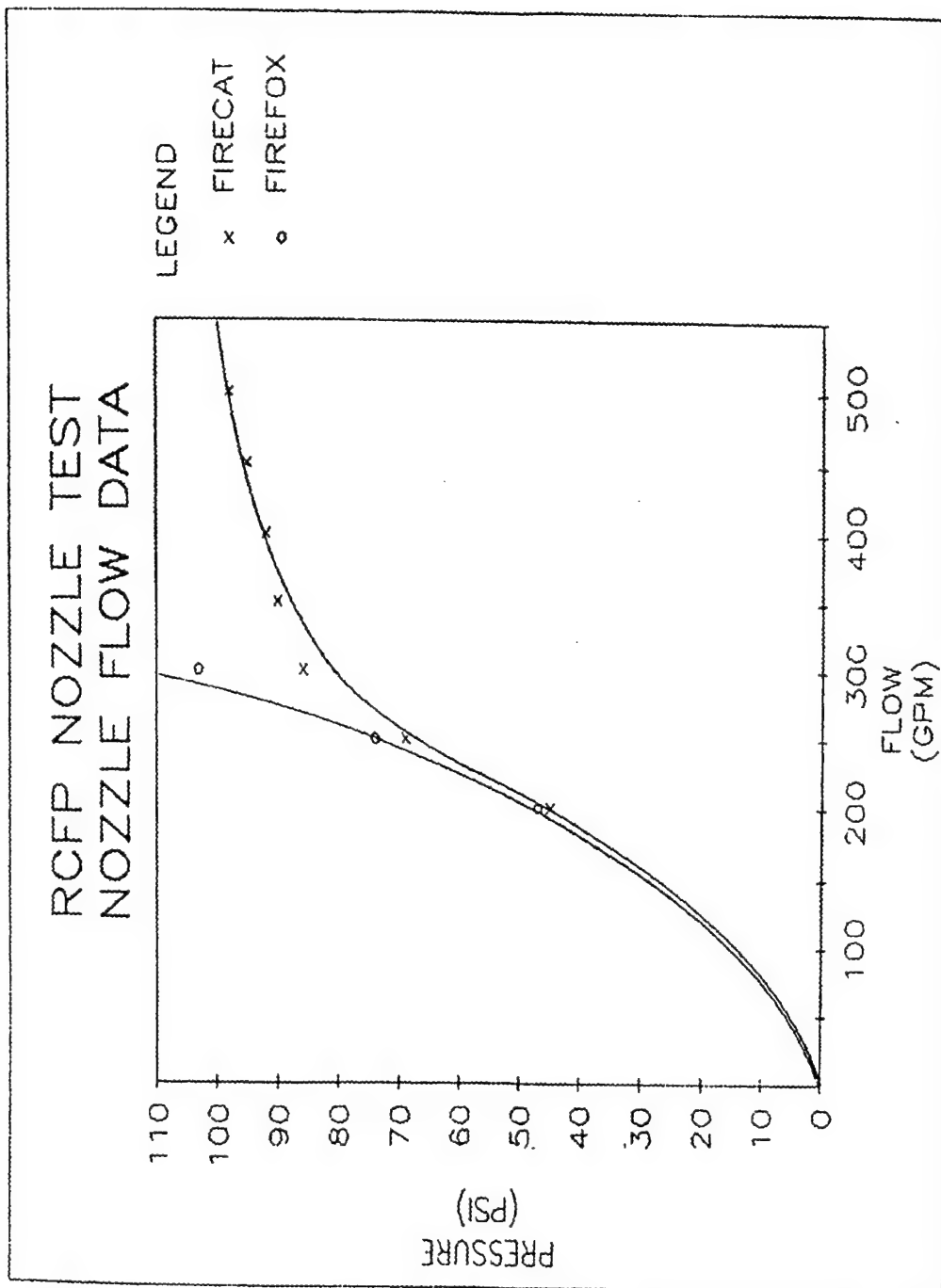


Figure 9 -- Flow vs. pressure curves for the RCFP nozzles

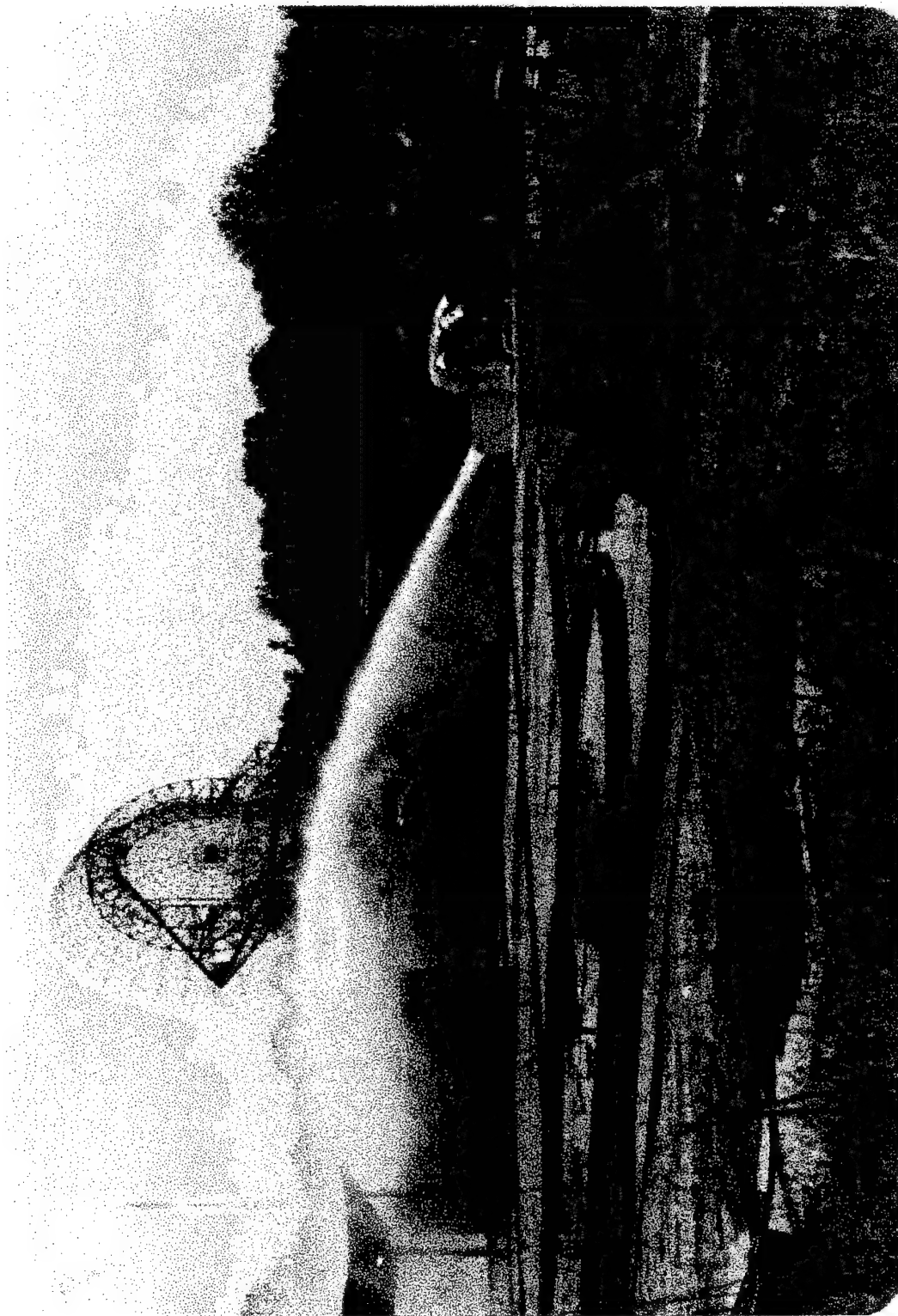


Figure 10 – Firecat during stream reach test

# RCFP NOZZLE TEST STREAM REACH DATA FIRECAT

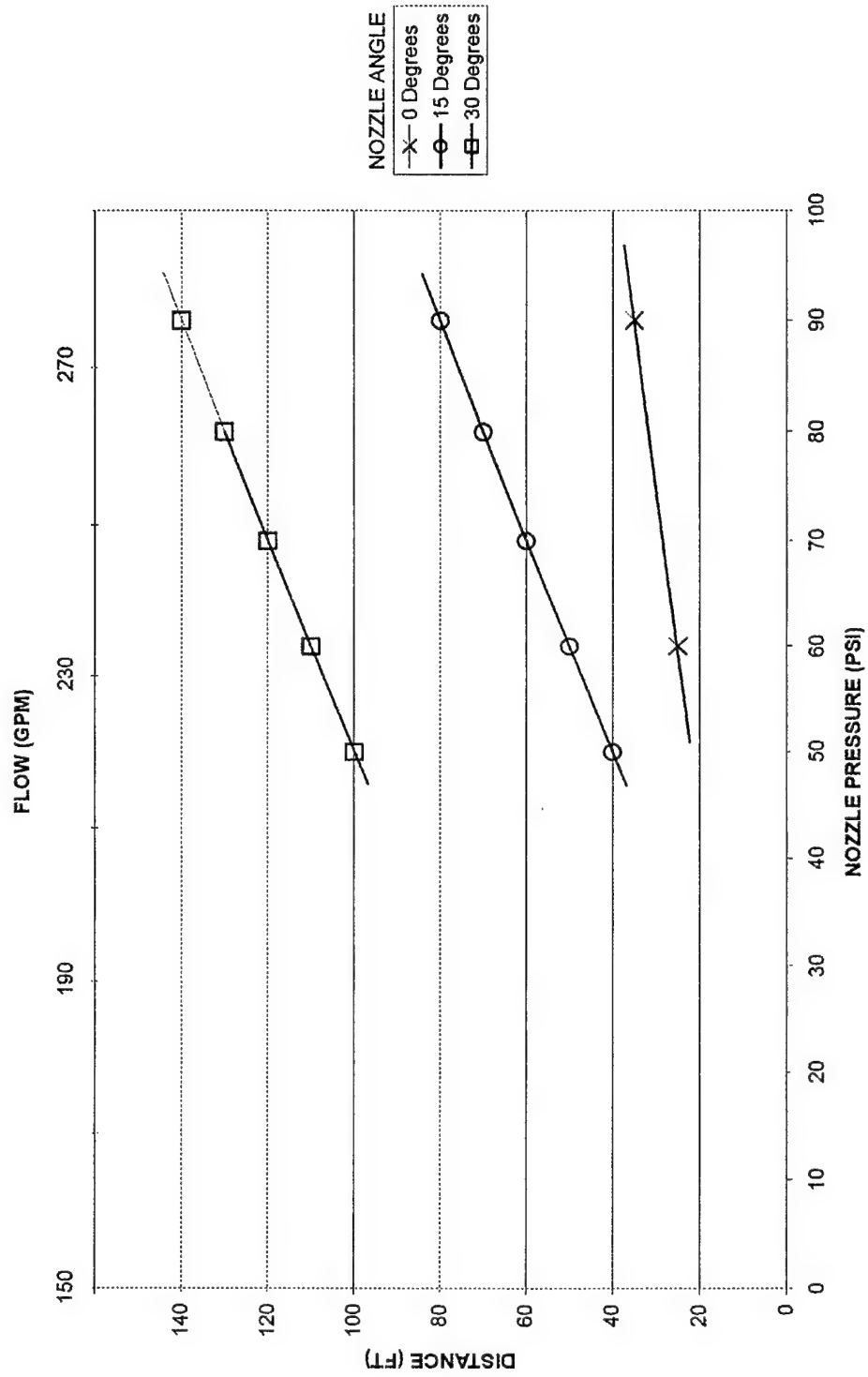


Figure 11 – Stream reach (0 wind) firecat

RCFP NOZZLE TEST  
STREAM REACH DATA  
FIREFOX  
STRAIGHT STREAM

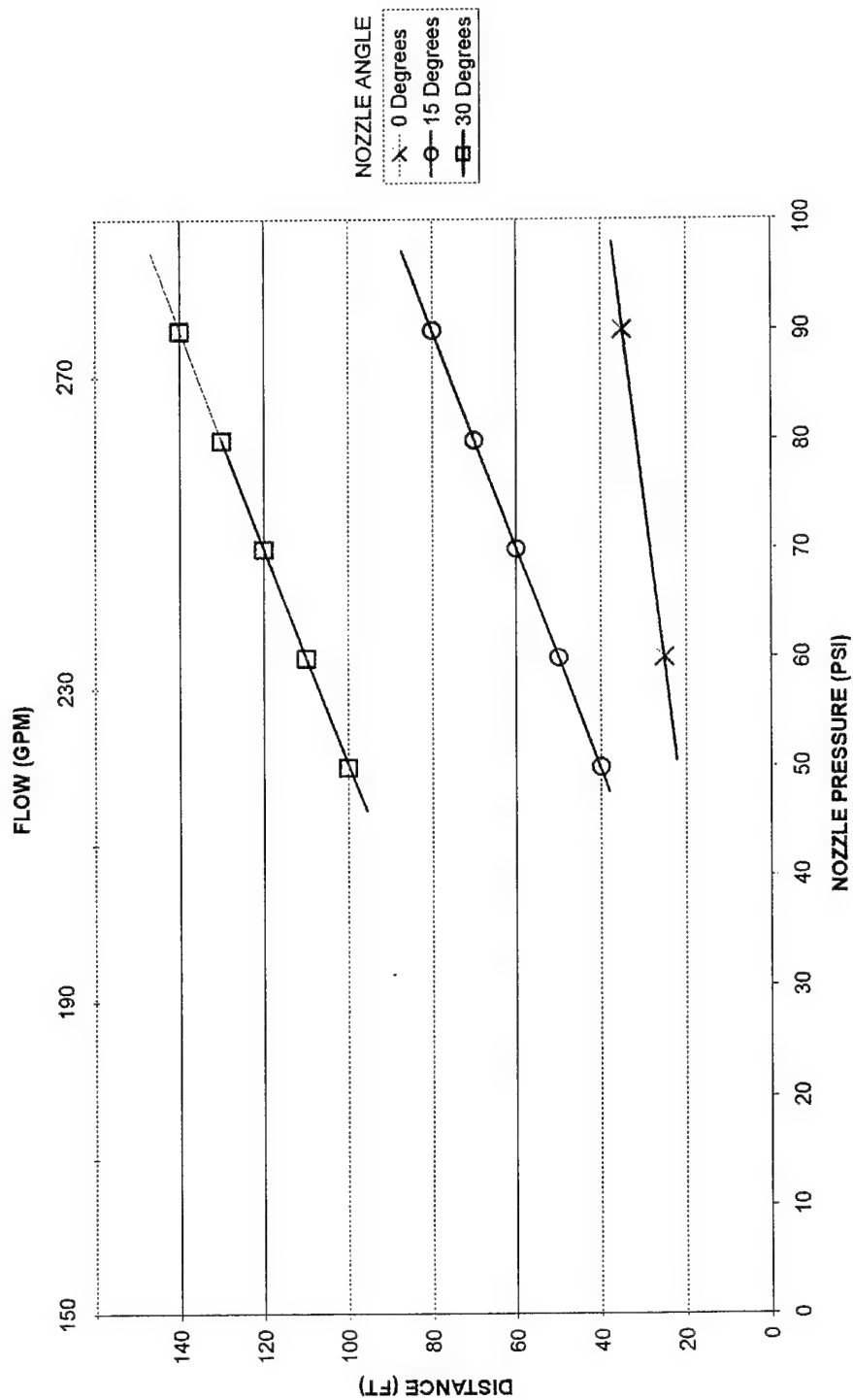


Figure 12 – Stream reach (0 wind) firefox



The data for the Feecon nozzle modification are presented throughout Tables 1-5 and are indicated by an asterisk (\*) after the test number.

These Tables contain the following information:

VEHICLE	–	The RCFP tested: CAT (Firecat), FOX (Firefox), or BOTH
TEST NO.	–	The number of the test, in the order they were conducted. Not all test numbers are reported because some tests were aborted due to operational problems and some inconsistencies in numbering occurred.
FLOW	–	The measured flow rate for AFFF during the test, in liters per minute (and gallons per minute).
WIND	–	The wind speed, in knots.
RANGE	–	The initial (when agent discharge began), and final, distance of the RCFP from the fire, in meters (and feet). If only one number is reported, this is the final distance.
CONTROL	–	The time to fire control, in seconds. (Control was defined as a minimum 90% knockdown of the visible flaming.) NONE indicates that the fire was neither extinguished nor controlled. The time of test termination is given in parentheses.
EXTINGUISHED	–	The time to achieve total extinguishment (cessation of all flames), in seconds.

The data on fire extinguishment for both RCFPs at various approach angles with and against a 30 knot wind are summarized in Tables 1 and 2. In general, the data show that the test fires could be controlled or extinguished in 150 seconds or less with or against the wind and at any angle of approach, up to 90 °, with either RCFP. However, the spread of the control and extinguishment data is too great and the number of tests conducted too few to draw any more specific conclusions regarding the optimum angle of approach.

When the RCFP was approaching the fire with wind (Table 1) or against the wind (Table 2) it was able to maneuver to within 8 m (25 ft) or less of the debris pile fire to achieve control or extinguishment. A photo of the Firefox attacking the debris pile fire is given in Figure 13.

The limited data on night firefighting (Table 3) indicate that the RCFPs can be effective at night since fire extinguishment was achieved with the Firefox by itself and with the Firecat, in less than 100 seconds.

Table 1 – Vehicle Approaching with the Wind

Vehicle/ Test No.	Flow (Lpm (gpm))	Wind (kts)	Range (m (ft))	Control (sec)	Extinguished (sec.)	Comments
Approach Angle 0 Degrees						
CAT/P-1	946 (250)	30	17-3 (55-10)	–	147	
CAT/P-1	946 (250)	30	17-3 (55-10)	30	–	
CAT/1	946 (250)	30	14-8 (45-27)	–	80	
CAT/25	946 (250)	30	17 (55)	–	30	
FOX/7	926 (250)	30	17-5 (56-15)	None (360)	–	
FOX/8	926 (250)	15	17-1 (56-3)	None (90)	–	
Approach Angle 30 Degrees						
CAT/2	946 (250)	30	14-4 (45-13)	None (140)	–	
CAT/3	946 (250)	30	14-6 (45-20)	None (160)	–	
CAT/26*	946 (250)	30	17 (55)	–	150	Nozzle problem
CAT/4	946 (250)	30	17 (55)	–	20	
FOX/11	946 (250)	30	14-4 (45-13)	–	100	
FOX/21	946 (250)	15	14-8 (45-26)	–	50	
FOX/9	1325 (350)	30	18-8 (58-25)	90	–	
FOX/10	1325 (350)	30	14-6 (45-20)	–	100	
Approach Angle 60 Degrees						
CAT/22	946 (250)	30	17 (55)	–	50	
CAT/23*	946 (250)	30	17 (55)	–	120	
CAT/24*	946 (250)	30	20-5 (65-15)	–	60	
Approach Angle 90 Degrees						
FOX/12	946 (250)	30	11-1 (34-3)	None (90)	–	Too close
FOX/28	946 (250)	30	8 (24)	60	–	
FOX/13	1325 (350)	30	11-5 (34-17)	None (120)	–	
CAT/5	1893 (500)	15	15 (50)	60		Pump cut out
CAT/6	1893 (500)	15	15-10 (50-30)	59	–	

\* Utilized Feecon Nozzle

Table 2 – Vehicle Approaching against the Wind

Vehicle/ Test No.	Flow (Lpm (gpm))	Wind (kts)	Range (m (ft))	Control (sec)	Extinguished (sec.)	Comments
Approach Angle 0 Degrees						
FOX/27	946 (250)	30	8 (25)	None (120)	–	
CAT/32	946 (250)	30	5 (17)	–	90	
CAT/39*	946 (250)	30	5 (17)	–	65	
Approach Angle 30 Degrees						
FOX/29	946 (250)	30	8 (27)	30	–	
CAT/35	946 (250)	30	8 (25)	–	66	
CAT/42*	946 (250)	30	8 (25)	–	56	
Approach Angle 60 Degrees						
FOX/30	946 (250)	30	10 (32)	35	–	
Approach Angle 90 Degrees						
CAT/33	946 (250)	30	5 (17)	80	–	
CAT/40	946 (250)	30	6 (20)	None (65)		
CAT/41	1512 (400)	30	6 (20)	None (51)		Couldn't reach in crosswind Stream blew through pile
CAT/34	1893 (500)	30	6 (19)	–	60	

\* Utilized Feecon Nozzle

Table 3 – Night Fires

Vehicle/ Test No.	Flow (Lpm (gpm))	Wind (kts)	Range (m (ft))	Control (sec)	Extinguished (sec.)	Comments
CAT/36	946 (250)	30	6 (18)	None	–	0 Degree Approach
FOX/37	946 (250)	30	6 (20)	–	99	0 Degree Approach
NOTH/38	946 (250) EA.	30	6/6 (20/20)	–	73	Worked against each other

Table 4 -Effect of Using a 2.4 m (8 ft) Boom on Firefighting

Vehicle/ Test No.	Flow (Lpm (gpm))	Wind (kts)	Range (m (ft))	Control (sec)	Extinguished (sec.)	Comments
Approach Angle 0 Degrees						
FOX/51*	946 (250)	30	6 (20)	42	-	
Approach Angle 30 Degrees						
FOX/52*	946 (250)	30	6 (20)	None (180)	-	
Approach Angle 60 Degrees to 0 Degrees						
FOX/54*	946 (250)	30	6 (20)	-	79	
Approach Angle 90 Degrees to 0 Degrees						
FOX/53*	946 (250)	30	6 (20)	-	175	
Approach Angle 90 Degrees						
FOX/55*	946 (250)	30	6 (20)	90	-	
FOX/56*	946 (250)	30	6 (20)	30	-	

\* All tests conducted with the Feecon nozzle

Table 5 - Effects of Increased Flow Rates on Extinguishment Time

Vehicle/ Test No.	Flow (lpm (gpm))	Wind (kts)	Range (m (ft))	Control (sec)	Extinguis hed (sec.)	Comments
FOX/9*	1325 (350)	30	18-8 (58- 25)	90	-	30 Degrees with wind
FOX/10*	1325 (350)	30	14-6 (44- 18)	-	100	30 Degrees with wind
FOX/13*	1325 (350)	30	11-5 (34- 17)	None (120)	-	30 Degrees with wind
FOX/41*	1512 (400)	30	6 (20)	None (51)	-	Blew through pile, 90 Degrees against wind
CAT/4*	1893 (500)	30	17 (55)	-	20	30 Degrees with wind
CAT/5*	1893 (500)	15	15 (50)	90	-	Pump cut out, 90 Degrees with wind
CAT/6*	1893 (500)	15	15-10 (50-30)	59	-	90 Degrees with wind
CAT/34*	1893 (500)	30	6 (19)	-	90	90 Degrees against wind
BOTH/38*	1893 (500)*	30	6/6 (20/20)	-	73	30 Degree & Fox 30 Degree with wind Night Fire
BOTH/18	1893 (500)*	30	15/14 (48/45)	-	30	Cat 30 Degree & Fox 0 Degree with wind
BOTH/19	1893 (500)*	30	12/8 (40/26)	-	60	Cat 90 Degree & Fox 30 Degree with wind
BOTH/20	1893 (500)*	15	12/14 (40/45)	-	50	Cat 90 Degree & Fox 30 Degree with wind

\* Results taken from the previous four Tables

\* Total, 946 lpm (250 gpm) from each RCFF

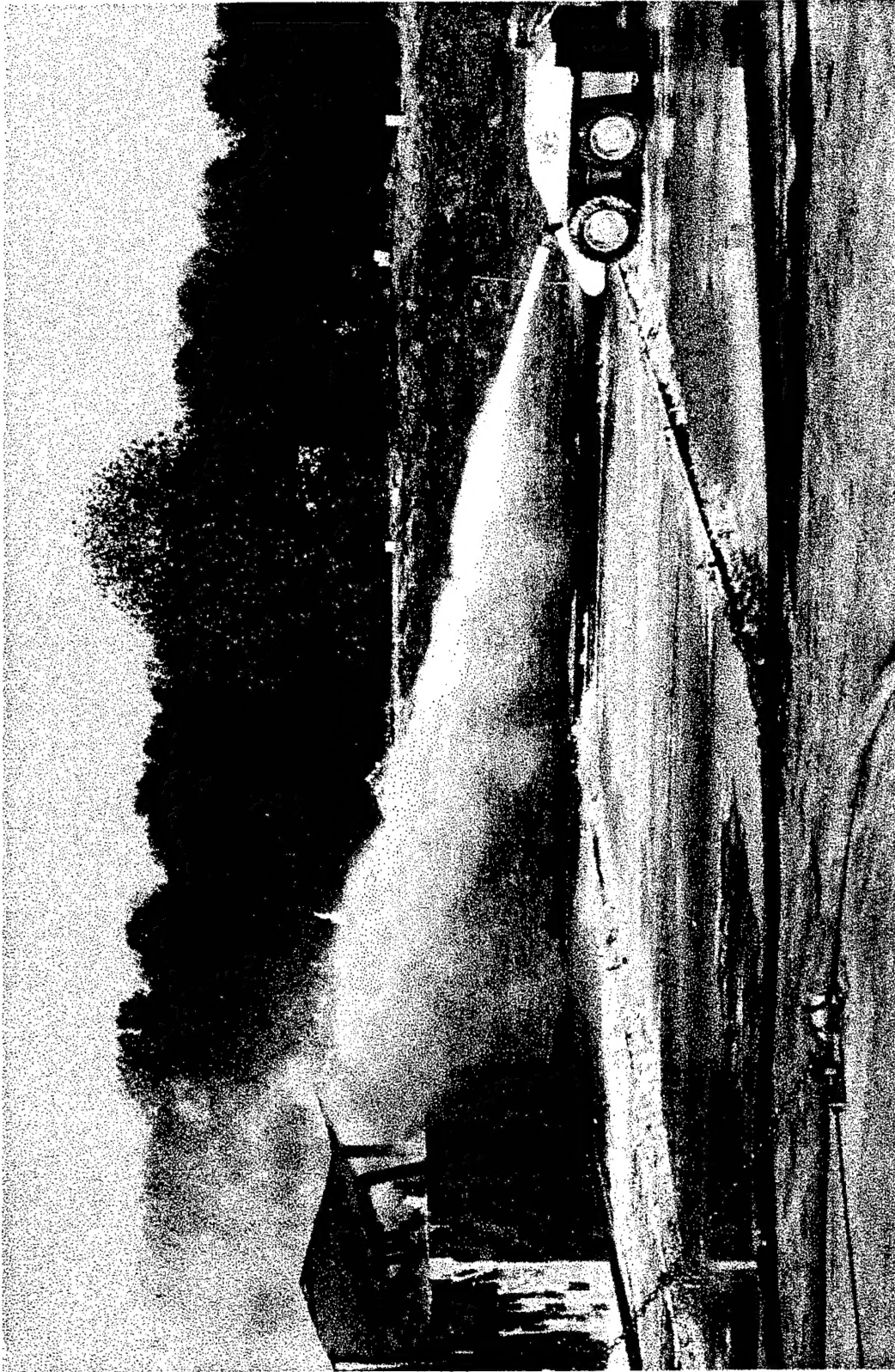


Figure 13 – Firefox attacking debris pile fire

The effect on fire suppression of mounting the firefighting nozzle on a 2.4 m (8 ft) boom is summarized in Table 4 for the two conditions tested. These data provide reasonable evidence that the use of the boom is at least as effective (and possibly more so) as the conventional nozzle arrangement. Unfortunately, these tests did not duplicate some easily envisioned configurations in which the 2.4 m (8 ft) boom might be extremely advantageous. These configurations include fires shielded behind a wall of debris which hose teams could not reach over and fires within a pile of debris into which the boom could be inserted.

The effect of increased flow rates on extinguishment or control is shown in Table 5. The data show that the probability of extinguishment/control increases dramatically with a significant increase in the flow rate. At flow rates of 1325 to 1512 Lpm (350 to 400 gpm), only one fire was not extinguished or controlled. When the flow rate was increased to 1893 Lpm (500 gpm), flowing either from one RCFP, or 946 Lpm (250 gpm) from each, the fire was always controlled or extinguished. Therefore, increasing the flow rate from the RCFP to 1893 Lpm (500 gpm) greatly improves its effectiveness. While the standard debris pile cannot be considered representative of all possible flight deck crash fires, it is sufficiently challenging to provide a realistic bench mark against which extinguishing equipment and methods can be evaluated. Any device or method which can successfully handle the standard debris pile, can be reasonably expected to achieve similar results against any real flight deck debris fire, as long as the device can get within the reach of its extinguishing agent stream.

A limited number of tests were conducted to compare the effectiveness of the RCFPs versus hand lines using an approach of 0 degrees (with the wind) and the same distance location, 15.3 m (50 ft) away from the fire. These data are presented in Table 6.

Table 6 – Comparison of Firefighting Capability for RCFP vs. Hand Lines (0 Degree Approach: 15.3 (50 ft) from Fire)

Method of Extinguishment	Flow (Lpm (gpm))	Number of Tests	Number Controlled/ Extinguished	Time Required
RCFP	946 (250)	6	4	30-147 sec
6.4 cm (2.5 in) Hose Line	756 (200)	1	1	60 sec
3.8 cm (1.5 in) Hose Line	378 (100)	1	1	60 sec

While only one data point is provided for each hose line test, previous test work [3-5] supports the conclusion that the 3.8 cm (1.5 in.) hose line achieved extinguishment at a flow rate only 40% that of the RCFP. The extinguishment time for both hand lines was 60 sec. These results do not imply that the RCFP concept should be abandoned in favor of hand lines, as the RCFP has numerous advantages in various situations. Rather this comparison shows that the RCFP operators cannot apply foam as effectively as the hand line operator. The hand line operator can play the foam stream rapidly back and forth over the fuel surfaces to achieve quick



knockdown. The RCFP operator was unable to duplicate this effectively due to the relatively slow speed of nozzle oscillation provided by the present remote control system.

## **8.0 SUMMARY AND CONCLUSIONS**

A total of 45 separate fire tests were conducted to evaluate the firefighting capabilities of the two RCFPs, operating either singly or together, in a variety of wind conditions, and utilizing varying approach angles. The vehicles were able to maneuver into close proximity (less than 8 m (25 ft)) and extinguish or control 34 of the 45 test fires in 150 seconds or less. These fires would have been difficult or impossible for unprotected hose line crews to extinguish, particularly in a down wind approach. In view of these results, the RCFP is considered a valuable concept for extinguishing fires on the flight deck without exposing personnel to the hazards of ordnance cook-off provided that certain modifications, such as increasing the flow rate, are made.

For example, under ideal conditions, such as an upwind approach, the RCFP was able to achieve control or extinguishment at a flow rate of 946 Lpm (250 gpm); but not in a crosswind approach. Increasing the flow rate to 1893 Lpm (500 gpm) greatly improved the probability of extinguishment in all wind conditions.

Based on the results of these tests it would appear that, while the RCFP could be a valuable adjunct to the existing fire extinguishing equipment available on the flight deck, it would probably not be the primary response vehicle in many fire situations. However, in major conflagrations, especially when ordnance is involved, it could provide the capability to control or extinguish many fires, which might otherwise burn until the fuel supply was exhausted. (This delay is unacceptable, as returning aircraft often have no alternative landing area, and because of the high probability of ordnance cook off in a prolonged flight deck fire.) The RCFP could provide a means of approaching fires from downwind and attacking fires behind or within debris. The RCFP could also provide ordnance cooling capability without unduly endangering personnel.

## **9.0 RECOMMENDATIONS**

- It is recommended that the flow rate of the RCFP be increased to 1893 Lpm (500 gpm) to enhance fire extinguishing capability.
- Consideration should be given to incorporating a 2.4 m (8 ft) boom into the next generation RCFP to increase its extinguishing capabilities.
- The speed of the nozzle sweep should be increased to improve the extinguishing capability of the RCFP. The ability to duplicate the rapid movements of a hose line would enable the operator to apply foam to the base of the fire in a more controlled fashion and avoid reflash problems.



## 10.0 REFERENCES

1. Carhart, H.W., Leonard, J.T., Darwin, R.L., Burns R.E., Hughes, J.T. and Jablonski, E.J., "Aircraft Carrier Flight Deck Firefighting Tactics and Equipment Evaluation Tests," NRL Memorandum Report 5952, February 26, 1987.
2. NATOPS U.S. Navy Aircraft Firefighting and Rescue Manual, NAVAIR 00-80R-14.
3. Darwin, R.L. and Jablonski, E.J., "Full Scale Fire Test Studies of Sea Water-Compatible "Light Water" as Related to Shipboard Fire Protection," Naval Ship Engineering Center, August 25, 1969.
4. Leonard, J.T., Fulper, C.R., Darwin, R., Back G.G., Burns R.E. and Oulette, R., "Fire Hazard of Mixed Fuels on the Flight Deck," NRL Memorandum Report 6975, April 28, 1992.
5. Darwin, R.L., and Williams, F.W., "A Review of the Performance of AFFF Systems Serving Helicopter Decks on U.S. Navy Surface Combatants," NRL Ltr Rpt Ser 6180/0657, 28 October 1999.